



CICT Sub-Project: Anomaly Detection in Aerospace Vehicles

Engineering Data Modeling for Failure Detection

- **Motivation:**
 - Develop capabilities and technologies to enable the early detection of component failures in aerospace systems
 - NASA mission-specifics: 1) increase aircraft reliability to assure transport safety; 2) reduce unscheduled maintenance costs and delays in civil and military aircraft to assure faster transport.
- **Task Goal and Objectives:**
 - Enable the automated separation of component failure signatures from noisy and highly variable dynamic data from engineered systems
 - Understand and model the variable nature of dynamic data from engineered systems
 - Initial problem: vibrations from “healthy” helicopter transmissions (lead: Dr. Irem Tumer and Prof. Todd Leen)
 - Current target problem: “healthy” data from aircraft engines and “faulty” data from testbeds and simulations (lead: Dr. Irem Tumer and Prof. Daniel McAdams)



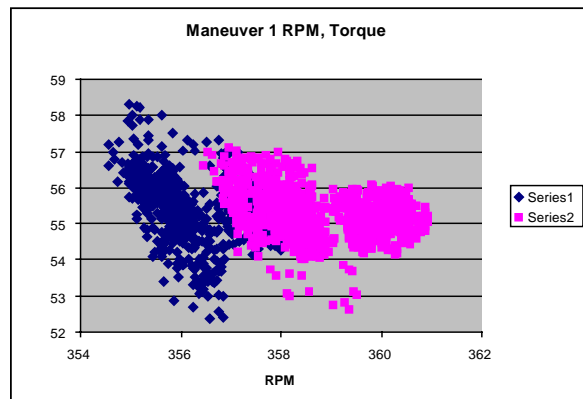
CICT Sub-Project: Anomaly Detection in Aerospace Vehicles

Problem:

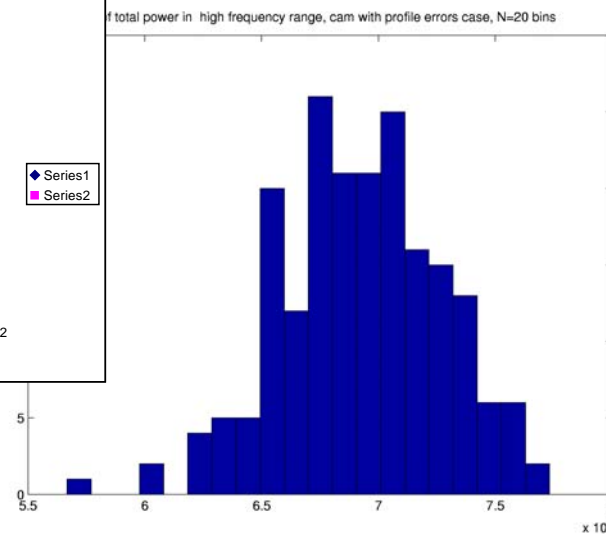
Detection of Failures based on dynamic data
in *engineered* systems



Flight data variability

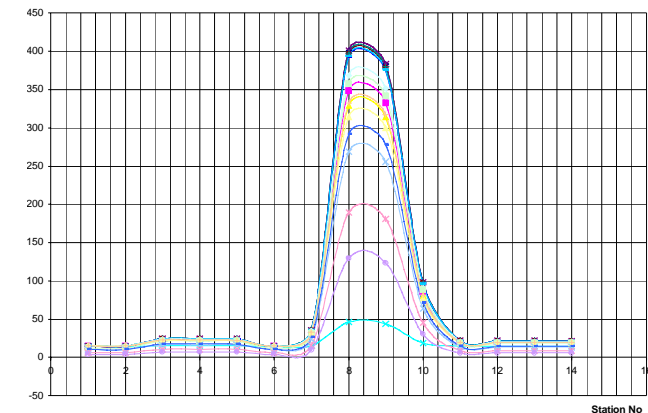


Design variability

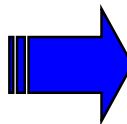


Simulation data

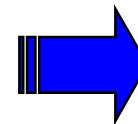
Pressure vs Station [Cases 1, 2, É, 17] of F117 Engine



Poor Models/assumptions



Data
Mismatch



Unreliable fault detection



CICT/IS/IDU Sub-Project: Anomaly Detection in Aerospace Vehicles

- **Technical Work Overview:**

- **Objectives**

- Generate the distributional characteristics of dynamic (flow) signals using engine models (Summer Student, Stanford University)
 - Develop and combine empirical and theoretical models that represent variations due to design and manufacturing and failures due to fatigue and cracks in simple beams (NASA-University Consortium, Cooperative agreement, University of Missouri-Rolla)

- ***Research challenges:***

- Variability in vibration data from engineered systems is not well understood resulting in inability to match empirical and modeled data/signatures
 - Very few failures exist in high-risk aerospace systems
 - Lots of data needed to model the distributional characteristics
 - Fault/anomaly detection systems fail in their functionality making automated fault detection unreliable in practice

- **Expected results and benefits:**

- Better models of variability
 - Less false positives in fault detection algorithms
 - More reliable vehicle monitoring systems



CICT/IS/IDU Sub-Project: Anomaly Detection in Aerospace Vehicles

- **Technical Work Approach:**
 - Technical Strategy
 - Combine variational modeling methods used in design and manufacturing research with damage models
 - Combine empirical and simulation data
 - Show feasibility using simple beams and extend to critical aircraft components (long term)
 - Organization
 - Performers :
 - Dr. Irem Tumer, Code IC/NASA ARC
 - Prof. Daniel McAdams, University of Missouri-Rolla
 - Graduate students
 - Facilities and laboratories:
 - University of Missouri-Rolla experimental facilities
 - Pratt and Whitney for models
 - NASA Dryden for C-17 aircraft data
 - Acquisition strategy (NRAs, NASA-University consortium cooperative agreement; NASA summer internships)



CICT/IS/IDU Sub-Project: Anomaly Detection in Aerospace Vehicles

- **Accomplishments in FY03 (Conf. Papers published/accepted)**
 - D.A. McAdams and I.Y. Tumer. Towards failure modeling in dynamic systems: impact of design and manufacturing variations. ASME Design for Manufacturing Conference, DERC2002/DFM-34161. Montreal, Canada. October 2002.
 - N.C. Oza, I.Y. Tumer, K. Tumer, E.M. Huff. Classification of aircraft maneuvers for fault detection. Multiple Classifier Systems Conference. Surrey, England. June 2003.
 - D.A. McAdams, D. Comella, I.Y. Tumer. Developing variational models of damaged beams: toward intelligent failure detection. ASME International Mechanical Engineering Congress and Exposition, IMECE 2003-42540. Washington, D.C., November 2003.
 - D.A. McAdams, D. Comella, I.Y. Tumer. Two methods for determining natural frequencies of cracked beams for intelligent fault detection. To be submitted to ASME Design for Manufacturing Conference.
- **Accomplishments in FY03 (Journal Papers submitted for review)**
 - D.A. McAdams, D. Comella, I.Y. Tumer. Failure Detection using combined variations and damage models. In review. Journal of Sound and Vibration
 - D.A. McAdams and I.Y. Tumer. Modeling variability in dynamic systems for vehicle health monitoring. In review. Journal of Vibration and Acoustics.
 - D.A. McAdams, D. Comella, I.Y. Tumer. Determining natural frequencies of cracked beams for fault detection. Journal paper in preparation.